

## TRACE FOSSILS FROM THE PHE FORMATION (LOWER CAMBRIAN), ZANSKAR VALLEY, NORTHWESTERN INDIA

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Trace fossils from the upper part of the Tsarap Member of the Phe Formation, Zanskar Valley, northwest India, provide the first evidence for the age of these strata. *Taphrhelminthopsis* cf. *circularis* and *Helminthopsis* sp. suggest an Early Cambrian age. *T. cf. circularis* in the absence of body fossils may indicate that these traces predate the trilobites and are correlative with the Tommotian. □ *trace fossil, Cambrian, Himalaya.*

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The lower Palaeozoic history of India is not well known, despite much recent work. The Zanskar region is particularly poorly understood, although a series of recent studies provide some understanding of the early Palaeozoic in this region (Nanda & Singh, 1976; Srikantia et al., 1980; Gaetani et al., 1986; Garzanti et al., 1986; Whittington, 1986). Trace fossils studies are currently of special significance because the Precambrian-Cambrian boundary is formally based on the appearance of key ichnogenera (Narbonne et al., 1987). This paper records trace fossils within the Phe Formation and constrains the position of the Precambrian-Cambrian boundary in this region.

### TRACE FOSSILS AND THE PRECAMBRIAN-CAMBRIAN BOUNDARY IN INDIA

Following Seilacher's (1955) pioneering work on the trace fossils of the Salt Range in Pakistan recent work in India has concentrated on the use of trace fossils for recognising the Precambrian-Cambrian boundary (Tandon & Bhatia, 1978; Bhargava et al., 1982; Bhargava & Srikantia, 1982; Raina et al., 1983; Kumar et al., 1983; Shah & Sudan, 1983, 1984; Singh & Rai, 1983; Kumar et al., 1984; Kumar, 1984). The diversity of trace fossils increases at stratigraphically higher levels in pre-trilobite bearing strata of India (Tandon & Bhatia, 1978; Raina et al., 1983; Kumar, 1984), which is consistent with patterns described from many sections worldwide (e.g. Fedonkin, 1979; Crimes & Anderson, 1985; Fritz & Crimes, 1985; Crimes, 1987; Narbonne & Myrow, 1988; Narbonne et al., 1987). The Precambrian-Cambrian boundary is formally defined on the basis of trace

fossils and, while initial progress has been made, much work is still needed before it can be accurately determined in the Indian Himalaya. Kumar et al. (1984, fig. 2) reported that *Phycodes* first occurs at the top of member A of the Lolab Formation in Kashmir, 750m above deposits containing Upper Riphean microflora. If complete, this section appears to be the best candidate for recognising the Precambrian-Cambrian boundary in India. A complete Precambrian-Cambrian boundary section may be present in the Krol-Tal belt, from which Ediacaran fossils (Mathur & Shanker, 1989; 1990), small shelly fossils (Bhatt et al., 1983) and archaeocyathids (Singh & Rai, 1983) have been reported. However, the Ediacaran faunas apparently occur above the small shelly fossils (Kumar, 1990), and the accuracy of some of these identifications is uncertain. M. Wade (pers. comm.) suspects that many, but not all, are algal or cyanobacterial mat structures.

### STRATIGRAPHY AND TRACE FOSSILS OF THE PHE FORMATION

#### STRATIGRAPHY

Lowermost Palaeozoic rocks in the Zanskar Valley are assigned to three formations; the basal, silt/sandstone-dominated Phe Formation, the dolomitic Karsha formation and the silt-dominated Kargiakh Formation (Garzanti et al., 1986). Although Garzanti et al. (1986) noted bioturbation in the Phe Formation they did not recognise any fossils. Trilobite fragments have been reported (Garzanti et al., 1986) within the Karsha Formation, and late Middle Cambrian trilobites occur in the Kargiakh Formation (Garzanti et al., 1986) (some 400 m above the top of

the Phe Formation). These relationships suggest that the Phe Formation is older than late Middle Cambrian; some of the Phe Formation might be Precambrian (Garzanti et al., 1986), raising the possibility of a Precambrian-Cambrian boundary section in Zanskar.

The Phe Formation comprises at least 800 m of siltstones and fine-grained sandstone (Garzanti et al., 1986). It is divided into a silt-rich lower Tsarap Member, and an upper sandier Doda Member (Nanda & Singh, 1976). Nanda & Singh (1976) recognised an uppermost Thonde Member, from which trilobites have been collected at Kargiakh nulla (Dungrakoti et al., 1974). The trilobites were assigned to *Ptychoparia* sp and *Asaphus* sp and, on this basis, it was suggested that the Phe Formation is Upper Cambrian to Lower Ordovician (Gupta, 1978). However, further work has shown that fossiliferous strata in Kargiakh nulla are not part of the Phe Formation. Instead they overlie the Karsha Formation. These deposits are now assigned to the Surichun Member of the Kargiakh Formation (Garzanti et al., 1986). Although subsequent collection of the Kargiakh nulla site yielded neither *Ptychoparia* nor *Asaphus* (these assignments are likely incorrect), the agnostid *Lejopyge laevigata* confirms a latest Middle Cambrian age (Whittington, 1986). A variety of mid Middle Cambrian trilobites have recently been collected from the Kargiakh Formation, some from limestones, by Mr. A. Dogra and Dr. Sat Paul of Jammu University and are currently being described. As there are no major unconformities or structural discontinuities between the Kargiakh, Karsha and Phe Formations the age of the Karsha/Phe Formations is pre-mid Middle Cambrian.

Gupta & Shaw (1981) reported and figured *Elipsocephalus hoffi* and *Agraulos* sp. which they claimed were collected from the Phe Formation in the Kargiakh and Doda valleys. Reasons to doubt the validity of this report include: 1, the grid co-ordinates given do not coincide with the positions of these localities; 2, the three dimensional, slightly distorted nature of their specimens contrasts with the condition of other Cambrian trilobites collected from the Himalaya, which are flattened and are strongly deformed; and 3, re-collection of this area by M. Gaetani and N.

Hughes has not revealed any fossils similar to those described by Gupta & Shaw (1981). Similar doubts about the reliability of Gupta & Shaw's (1981) paper has been recorded by Whittington (1986) and their paper should be disregarded, in line with the suggestion of Talent et al. (1990).

#### TRACE FOSSILS

The Phe Formation was examined at several localities but trace fossils were observed only in the section due north of the village of Purni (33°8'24"N, 77°6'6"E) which corresponds to Section 1 on the map of Garzanti et al. (1986). These traces were described and photographed in situ and were not collected.

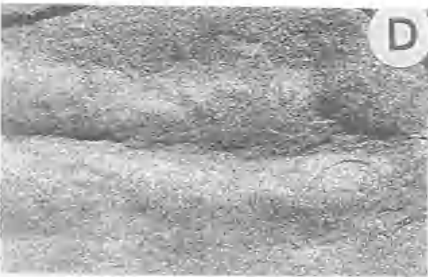
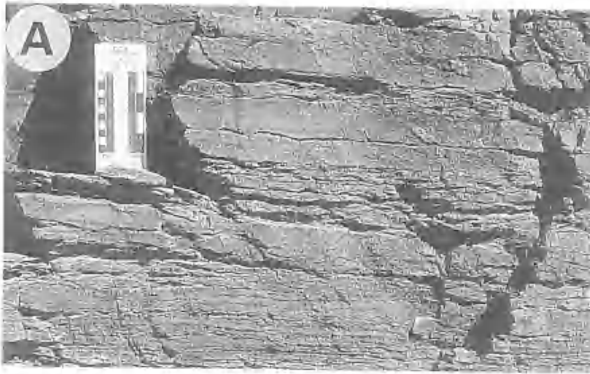
Within this section, traces occur in the upper part of the Tsarap Member of the Phe Formation, which is predominately composed of heterolithic dark grey siltstones and very fine grained light grey/buff sandstones. Sandstones are thinly bedded (1-5cm) and may be parallel, hummocky or cross stratified. Siltstones range from thin laminae to very thin beds (0.2-3.0cm). Where ripple structures are well preserved, wavy bedding is recognised (Fig. 1A). Wave, current, and interference ripples are all common on bedding surfaces (Fig. 1H). Short, narrow tool marks indicate palaeoflows towards the WSW. Slump features are common. The Phe Formation was deposited in an intertidal to shallow subtidal setting (Garzanti et al., 1986; pers. obs. N.C.H.).

Trace fossils are common on several bedding surfaces at the base of the section 100m north of Purni village. *Taphrhelminthopsis* cf. *circularis* (Fig. 1B-D) is most common occurring as a bilobate structure with a well defined, broad central furrow. Burrow width is 1.5-2.0cm. The furrow is about 0.2-0.3 of the width of the trace fossil. The trace fossils are sinuous to arcuate and up to 50cm long. Striations are not present. No complete circles were observed so specific assignment is questionable.

*Helminthopsis* (Fig. 1G) occurs as a groove, 0.2-0.4cm wide consisting of a central furrow with raised levees or as a full burrow. Traces are up to 15cm long, forming irregular meanders that were not observed to cross and commonly occur on rippled surfaces.

The tops of vertical burrows, 0.5-0.7cm in

FIG. 1. All photos except E from Upper Tsarap Member, 100 metres north of Purni, Zanskar. A, Interbedded silt and sand layers showing wavy bedding. B, *Taphrhelminthopsis* cf. *circularis* on bedding surface,  $\times 0.2$ . C, *Taphrhelminthopsis* cf. *circularis* on bedding surface,  $\times 0.5$ . D, detail of *Taphrhelminthopsis* cf. *circularis*,  $\times 1$ . E, bedding surface showing abundant *Planolites* and other traces, scree slope between Purni and Testa, probably from Tsarap Member,  $\times 0.3$ . F, back filled burrow,  $\times 1$ . G, *Helminthopsis* on bedding surface,  $\times 1$ . H, Bedding surfaces showing wave, current and interference ripples.



diameter, some apparently paired, are present on bedding surfaces, but no cross sections of these burrows were observed. Horizontal *Planolites* burrows, up to 0.8cm wide and 7.0cm long, are also present. One possible example of a back-filled burrow (Fig. 1F) occurs in siltstones. The burrow is infilled with very fine sand.

A slab of Phe Formation in scree on the track between Purni and Testa villages (Fig. 1E) shows abundant horizontal traces and vertical *Skolithos* burrows, which are 0.5cm wide and unpaired. In cross section this slab shows an ichnofabric index of 3 (Droser & Bottjer, 1986).

### DISCUSSION

The trace fossils indicate that these deposits are no older than Vendian. *Taphrhelminthopsis* is characteristic of Cambrian and younger strata (Crimes, 1987, in press). Fritz & Crimes (1985) reported *Taphrhelminthopsis* from Precambrian strata from the Cassiar Mountains, British Columbia but Crimes (1987) suggested that *Taphrhelminthopsis* in these strata indicates that perhaps the boundary in this section should be lower. In the current Precambrian-Cambrian boundary stratotype in Newfoundland *Taphrhelminthopsis* first occurs in the second trace fossil zone, (*Rusophycus avalonensis*) above the Precambrian-Cambrian boundary (Narbonne & Myrow, 1988).

*Helminthopsis* similarly first appears in Cambrian strata in well documented sections (Crimes, 1987) and is also thought to be characteristic of Phanerozoic strata. Both genera occur throughout the Phanerozoic and therefore do not further constrain the age. However, *Taphrhelminthopsis circularis*, appears to range from just above the first Phanerozoic-type traces to just below the first trilobites (Crimes, 1987, in press).

*Skolithos*, *Planolites* and simple back filled burrows, all appear in the Vendian and range through the Phanerozoic and therefore do not aid in age resolution.

Crimes (1992) recognised an evolutionary development of simple sediment filled burrows from the Precambrian to the Cambrian. The straight to slightly curved *Planolites* first occurs in Vendian deposits. Slightly more complex irregularly meandering burrows which cross, such as *Gordia*, occur later in the Vendian. Burrows which spiral and have first-order meanders appear subsequently. *Helminthopsis*, which consists of irregular, but non-crossing first and second order meanders normally first occur in Cambrian strata,

and are characteristic of the Early Cambrian. Crimes (1992) reported increasing complexity of 'stuffed' burrows, with the meandering bilobate stuffed burrow *Taphrhelminthopsis* characterising Early Cambrian deposits.

We suggest that at least the upper part of the Tsarap Member is of Early Cambrian age based on *Helminthopsis* and *Taphrhelminthopsis*, and particularly the close similarity to *T. circularis*. If *T. circularis* is restricted to the pre-trilobite Cambrian (Crimes, 1987), it could explain the absence of body fossils in the Phe Formation. The Precambrian-Cambrian boundary may lie within the lower, unfossiliferous 200m of the Tsarap Member of the Phe Formation.

Like most other Early Cambrian trace fossil assemblages (Crimes & Anderson, 1985; Crimes, 1987) the fossils from the Phe Formation are found in shallow, nearshore deposits. *Taphrhelminthopsis* is common in the Lower Cambrian of India, occurring in the Himalaya in southeastern Kashmir (Bhargava & Srikantia, 1982) and in the Lesser Himalaya in the Tal Formation near Kauriyala, Uttar Pradesh (Kumar et al., 1983), and possibly near Mussoorie (Singh & Rai, 1983).

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